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The first *Stalicoolithus shifengensis* discovered in a clutch from the Sanshui Basin, Guangdong Province

ZHU Xu-Feng[1,3] FANG Kai-Yong[1,2] WANG Qiang[1*] LU Xiao-Hong[4]
WU Wei-Qiang[4] DU Yan-Li[5] HUANG Zhi-Qing[5] WANG Xiao-Lin[1,3]

(1 *Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences*, *Institute of Vertebrate Paleontology and Paleoanthropology*, *Chinese Academy of Sciences* Beijing 100044
* Corresponding author: wangqiang@ivpp.ac.cn)
(2 *School of Earth Sciences and Resources*, *China University of Geosciences*, *Beijing* Beijing 100083)
(3 *University of Chinese Academy of Sciences* Beijing 100049)
(4 *Nanhai Museum* Foshan, Guangdong 528211)
(5 *Heyuan Museum*, *Heyuan Dinosaur Museum*, *Dinosaur Egg Museum of Paleozoological Museum of China* Heyuan, Guangdong 517000)

Abstract The first clutch of *Stalicoolithus shifengensis* is described here. This incomplete dinosaur egg clutch in which three nearly complete eggs and two egg prints were preserved was discovered in the red deposits of the Sanshui Formation at a construction site near the sluice of North Village, Dali Town, Nanhai District, Foshan City, Guangdong Province, China. The eggs in the clutch are stacked with various ranges. Based on the characteristics of the eggshell, these eggs can be assigned to *S. shifengensis*. The discovery of *S. shifengensis* in the Sanshui Formation complements the clutch information about the oospecies as well as expands its paleogeographic distribution, and sets the foundation for discussing the diversity of dinosaur eggs in the Sanshui Basin.

Keywords Sanshui Basin, Guangdong, Late Cretaceous, dinosaur egg, Stalicoolithidae

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1 Introduction

Sanshui Basin is one of the beaded Mesozoic-Cenozoic red basins along the southeastern coast of China. It is located in the northwestern region of the Pearl River Delta, which includes Guangzhou, Foshan, Nanhai and Sanshui, Sihui and Gaoyao, as well as part of Qingyuan and covers an area of approximately 3300 km^2 (Hou et al., 2007). The Cretaceous strata in the Sanshui Basin were established based on drilling data, and from bottom to top are divided into the Lower Cretaceous Baihetong Formation, Upper Cretaceous Sanshui Formation and Dalangshan Group (Zhang, 1984).

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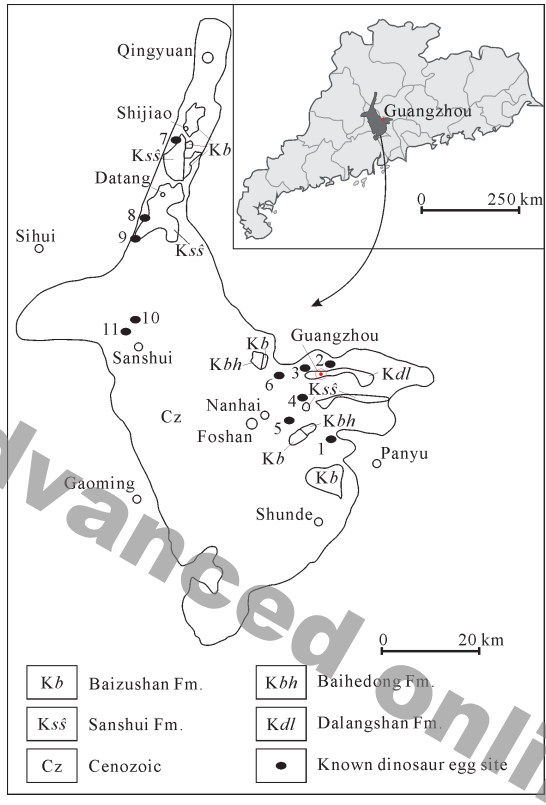

Fig. 1 The distribution of dinosaur egg sites in the Sanshui Basin (Basin boundary modified from Zhang et al., 2008; stratum distribution according to 1:200000 geological map, F4912, online data)
1. Zhong Village; 2. Meihua Village; 3. Jixiang Road; 4. Baihedong; 5. Pingzhou; 6. North Village; 7. Shijiao Town; 8. Datang Industrial Park; 9. Beijiang Dike; 10. Sanshui Second Bridge; 11. Hekou Geological Team Base

The discovery of the first dinosaur eggs in the Sanshui Basin can be traced back to the 1970s when workers at the Guangzhou Iron and Steel Plant found a clutch of 12 spheroid eggs and two partially preserved elongated eggs in the red deposits located 13 m underground (Sun Yat-sen University, 1976). Then in the Pingzhou-Guangzhou Iron and Steel Plant-Fangcun area, two clutches with 27 elongated eggs and a clutch with seven eggs of *Paraspheroolithus* were found (Sun Yat-sen University, 1976; Zhang and Huang, 1999). According to Zhang et al. (2009)[1)], dino-saur eggs were found within the red deposits of the Cretaceous Sanshui Formation at a construction site in Datang Industrial Park, Sanshui District, as well as at Sanshui Second Bridge, Beijiang Dike, and on the west side of the Hekou Geological Team Base. Egg clutches composed of elongated and spheroid eggs were found in several places in Shijiao Town, Qingyuan (Fig. 1).

The records of dinosaur eggs in Sanshui Basin are concentrated in two areas: from Sanshui to Qingyuan in the northwestern part of the basin, and from Foshan to Guangzhou in the eastern part of the basin (Fig. 1). Zhang and Huang (1999) pointed out that in the Sanshui Basin the lower layer bearing spheroid eggs belongs to the first member of the Baihedong Group (or Baihedong Formation), and the middle layer bearing spheroid and elongated eggs belongs to the first member of the Sanshui Formation. Considering the facts mentioned above, we believe that the dinosaur egg-bearing red deposits this paper discusses should be classified as part of the Sanshui Formation.

2 Systematic paleontology

Stalicoolithidae Wang et al., 2012

1) Zhang X Q, Zhang X J, Lin X Y, 2009. New knowledge of vertebrate fossils in Sanshui Basin. Paper presented at the 10th national congress of Palaeontological Society of China (PSC) & the 25th annual conference of PSC. Nanjing.

Stalicoolithus **Wang et al., 2012**

Stalicoolithus shifengensis **Wang et al., 2012**

Described specimen B 2017-1, an incomplete clutch (Fig. 2). The specimen is part of the collection at the Nanhai Museum.

Locality and horizon North Village, Dali Town, Nanhai District, Foshan City, Guangdong Province; Upper Cretaceous, Sanshui Formation.

Diagnosis Eggs are stacked in the clutch and are spheroids with an average diameter of 10.5 cm on average. The eggshell is 3.50 mm thick on average, and is constructed of eggshell units that show columnar extinction under cross-polarized light. The boundary between the cone layer and the columnar layer is not distinct. The columnar layer can be divided into inner, medial and outer zones. The secondary eggshell units are well developed in the medial and outer zones of the columnar layer. The pore canals are wormlike.

Description An incomplete clutch with at least five eggs comprising three nearly complete eggs and two egg prints stacked in the clutch with various ranges (Fig. 2). The eggs are spheroids with an average diameter of 10.5 cm. The average thickness of the eggshell is 3.50 mm. The eggshell is constructed out of closely arranged eggshell units, which show columnar extinction under cross-polarized light (Fig. 3A, B). The boundary between the cone layer and the columnar layer is not obvious. The cone layer is 0.25 mm thick on average,

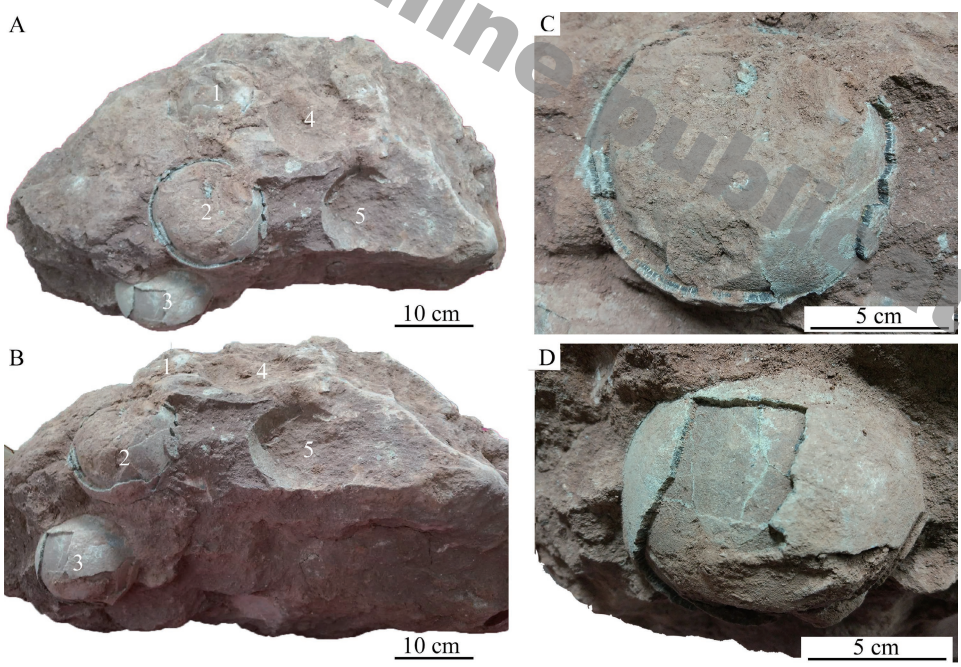

Fig. 2 The clutch of *Stalicoolithus shifengensis*

A. B 2017-1, showing the incomplete clutch composed of five dinosaur eggs of *Stalicoolithus shifengensis* in top view, No. 1, 2, 3 are near complete eggs while No. 4, 5 are only egg prints;

B. the clutch in lateral view showing the arrangement of the eggs in a different horizontal plane;

C, D. magnification figures of No. 2 (C) and No. 3 (D)

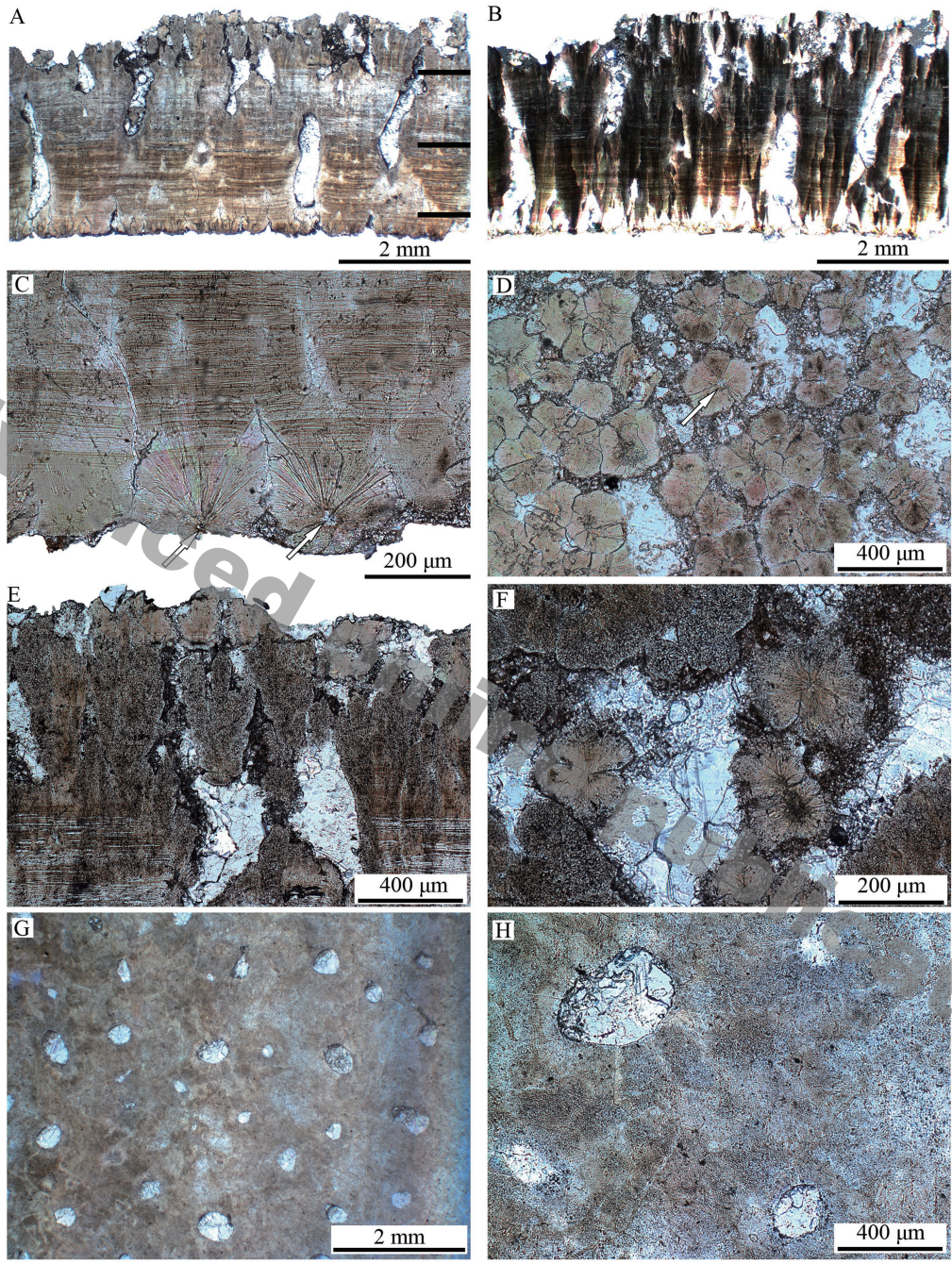

Fig. 3 Microstructure of *Stalicoolithus shifengensis*

A. radial section of eggshell, showing the boundaries of the cone layer, the inner zone of the columnar layer, the medial zone of the columnar layer and the outer zone of the columnar layer; B. radial section of eggshell (under cross-polarized light); C. radial section through the cone layer, white arrow indicate the position of organic core; D. tangential view of the cone layer, white arrow indicates the position of the organic core; E. radial section through the outer zone of the columnar layer showing the secondary eggshell units arranged in multiple layers; F. tangential view of the outer zone of the columnar layer showing the secondary eggshell units in irregular shaped pores; G–H. tangential views of the medial zone of the columnar layer showing the round and oval pores and their distribution

which is approximately 1/14 of the eggshell thickness. The cone is flower-like, and the cone gaps are significant (Fig. 3C, D). The columnar layer is 3.25 mm thick on average and it can be divided into three zones (Fig. 3A): the average thickness of the inner zone of the columnar layer is 1.25 mm (about 5/14 of the eggshell thickness) and displays obvious horizontal accretion lines; the medial zone of the columnar layer is 1.25 mm thick on average (about 5/14 of the eggshell thickness) and is characterized by bright strips; the outer zone of the columnar layer is composed of loosely arranged eggshell units, it is 0.75 mm thick on average (about 3/14 of the eggshell thickness) and is characterized by a large number of multilayer stacked secondary eggshell units (Fig. 3E, F). The pore canals are wormlike in radial section (Fig. 3A), round or oval in the tangential view of the medial zone of the columnar layer with an uneven distribution (Fig. 3G, H), and are irregular in the tangential view of the outer zone of the columnar layer (Fig. 3F).

The macrostructure and microstructure of the dinosaur eggs found in Foshan can be compared to *Stalicoolithus shifengensis* from the first member of the Chichengshan Formation, Upper Cretaceous, Tiantai Basin, Zhejiang. The holotype of *S. shifengensis* found in Tiantai Basin is a single egg (Wang et al., 2012). Although the clutch found in Foshan is incomplete, we can still obtain some of the clutch's information of *S. shifengensis*. The dinosaur eggs are stacked in the egg clutch without obvious arrangement and spaced apart from each other.

Liu et al. (2016) reported a clutch of dinosaur eggs found in Pingshan, Shenzhen in 2013 and identified them as *Pinnatoolithus*. However, *Pinnatoolithus* is a synonym for *Ovaloolithus* (Zhao et al., 2015). The misclassification happened when Liu et al. (2016) compared microscopic photographs of a radial section of her eggshells with those of Fang's *Pinnatoolithus* (2009) and she did not notice that their specimens were placed in opposite directions (see Liu et al., 2016:fig. 4A–D; Fang et al., 2009:figs. 3–5). Here, we suggest that it should be standard practice to arrange photographs of radial sections of eggshells with the outer surface on top to avoid such mistakes. The previously described columnar layer is actually the medial and outer zone of the columnar layer of a typical Stalicoolithidae, and the described mammillary layer (or cone layer), which is on average half the thickness of the eggshell, is the equivalent of the inner zone of the columnar layer and the cone layer of the Stalicoolithidae. Histostructural differences between the eggs of the Stalicoolithidae and the eggs we describe here are scarce. Prior to further observation, we advise that the specimen mentioned by Liu et al. (2016) should be identified as a member of the Stalicoolithidae.

3 The age of dinosaur egg-bearing red deposits in the Sanshui Basin

There are different understandings of the age of dinosaur egg-bearing red deposits in the Sanshui Basin. Based on paleomagnetic data, Yuan and Wang (1992) argued that the age of the Baihedong Group is 128–93 Ma, which ranges from the middle and late stages of the Early Cretaceous to the early stages of the Late Cretaceous , and that the age of the first member of Sanshui Formation is 93–83 Ma, which belongs to the early and middle stages of the Late

Cretaceous. Zhang and Huang (1999) agreed with this view in their summary of dinosaur egg-bearing layers and their distribution in Guangdong. According to the division of ostracods, the Sanshui Group can be compared with the Nanxiong Group, which belongs to the early and middle stages of the Late Cretaceous (Zhang et al., 2008). The age of the Chichengshan Formation in the Tiantai Basin is about 94–91 Ma (He et al., 2013) and belongs to the early stages of the Late Cretaceous similarly to that of the Sanshui Formation.

4 Paleogeographic distribution of *Stalicoolithus shifengensis*

The *Stalicoolithus shifengensis* in Foshan, Guangdong represents the first discovery of this oospecies outside its type locality the Tiantai Basin, Zhejiang Province, which provides new paleontological material for the classification and comparison of the Late Cretaceous continental red deposits in the Sanshui Basin and enriches the paleogeographic distribution of the Stalicoolithidae. In addition, this study is the first detailed description of the discovery of dinosaur eggs in the Sanshui Basin and therefore will lay a foundation for exploring the diversity of dinosaur eggs in the Sanshui Basin.

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广东三水盆地发现首个始丰石笋蛋(*Stalicoolithus shifengensis*)蛋窝

朱旭峰[1,3] 方开永[1,2] 王 强[1] 卢筱洪[4] 吴伟强
杜衍礼[5] 黄志青[5] 汪筱林[1,3]

(1 中国科学院古脊椎动物与古人类研究所，中国科学院脊椎动物演化与人类起源重点实验室 北京 100044)

(2 中国地质大学(北京)地球科学与资源学院 北京 100083)

(3 中国科学院大学 北京 100049)

(4 南海博物馆 广东佛山 528211)

(5 河源市博物馆，河源市恐龙博物馆，中国古动物馆恐龙蛋馆 广东河源 517000)

摘要： 描述了发现于中国广东省佛山市南海区大沥镇北村水闸施工工地的三水组红层中的首个始丰石笋蛋(*Stalicoolithus shifengensis*)蛋窝。这一不完整蛋窝保存有三个近完整蛋化石

和两个印痕。基于以下宏观形态和蛋壳显微特征，这些蛋可以被归为石笋蛋类的始丰石笋蛋：恐龙蛋呈球形，平均直径为10.5 cm; 蛋壳较厚，平均厚度为3.50 mm, 由柱状消光的壳单元组成，锥体层与柱状层界线不明显；锥体层的厚度为0.25 mm, 约占蛋壳厚度的1/14, 锥体在弦切面下呈花瓣状；柱状层可分为内层、中间层和外层，其中中间层和外层发育大量次生壳单元，气孔道呈蠕虫状。三水组中始丰石笋蛋的发现补充了这一蛋种的蛋窝信息：恐龙蛋在蛋窝中互相叠加，且相互之间间隔一定的距离。同时，这一发现还拓展了这一蛋种的古地理分布，为讨论三水盆地恐龙蛋的多样性奠定了基础。

关键词：三水盆地，广东，晚白垩世，恐龙蛋，石笋蛋科

References

Fang X S, Li P X, Zhang Z J et al., 2009. Cretaceous strata in Nanxiong Basin of Guangdong and the evolution from the dinosaur egg to the bird egg. Acta Geosci Sin, 30(2): 167–186

He H Y, Wang X L, Wang Q et al., 2013. Sims zircon U-Pb dating of the Late Cretaceous dinosaur egg: bearing red deposits in the Tiantai basin, southeastern china. J Asian Earth Sci, 62: 654–661

Hou M C, Chen H D, Tian J C et al., 2007. Sedimentary facies and palaeogeography of the Sanshui Basin, Guangdong during the Pelaeogene. Sedi Geol Tethyan Geol, 27(2): 238–244

Liu C L, Yin J, Zhu Z Y et al., 2016. Dinosaur eggs found in Pingshan, Shenzhen and their geological significance. Acta Sci Nat Univ Sunyatseni, 55: 158–161

Sun Yat-sen University, 1976. First discovery of dinosaur eggs from red deposits in Baihedong Group, Guangzhou. Acta Sci Nat Univ Sunyatseni. 2: 137–138

Wang Q, Wang X L, Zhao Z K et al., 2012. A new oofamily of dinosaur egg from the Upper Cretaceous of Tiantai Basin, Zhejiang Province, and its mechanism of eggshell formation. Chin Sci Bull, 57: 2899–2908

Yuan Y R, Wang B B, Tang X Z et al., 1992. Cretaceous-Early Tertiary paleolatitude migration in Sanshui Basin of south China and the evolution of South China Sea. J Trop Oceanograph, (1): 37–44

Zhang W, Huang P Y, 1999. The strata with fossil dinosaur eggs and their distribution in Guangdong. J Stratigr, 23(2): 89–95

Zhang X Q, 1984. On the subdivision and correlation of the Cretaceous System of Sanshui Basin of Guangdong. Petrol Geol Exper, 6(1): 36–44

Zhang X Q, Li G, Yang R L et al., 2008. Late Cretaceous ostracods from the Sanshui Basin of Guangdong. Acta Micropalaeontol Sin, 25(2): 132–165

Zhao Z K, Wang Q, Zhang S K, 2015. Dinosaur Eggs. Palaeovertebrata Sinica. Vol II, Fascicle 7. Beijing: Science Press. 1–168